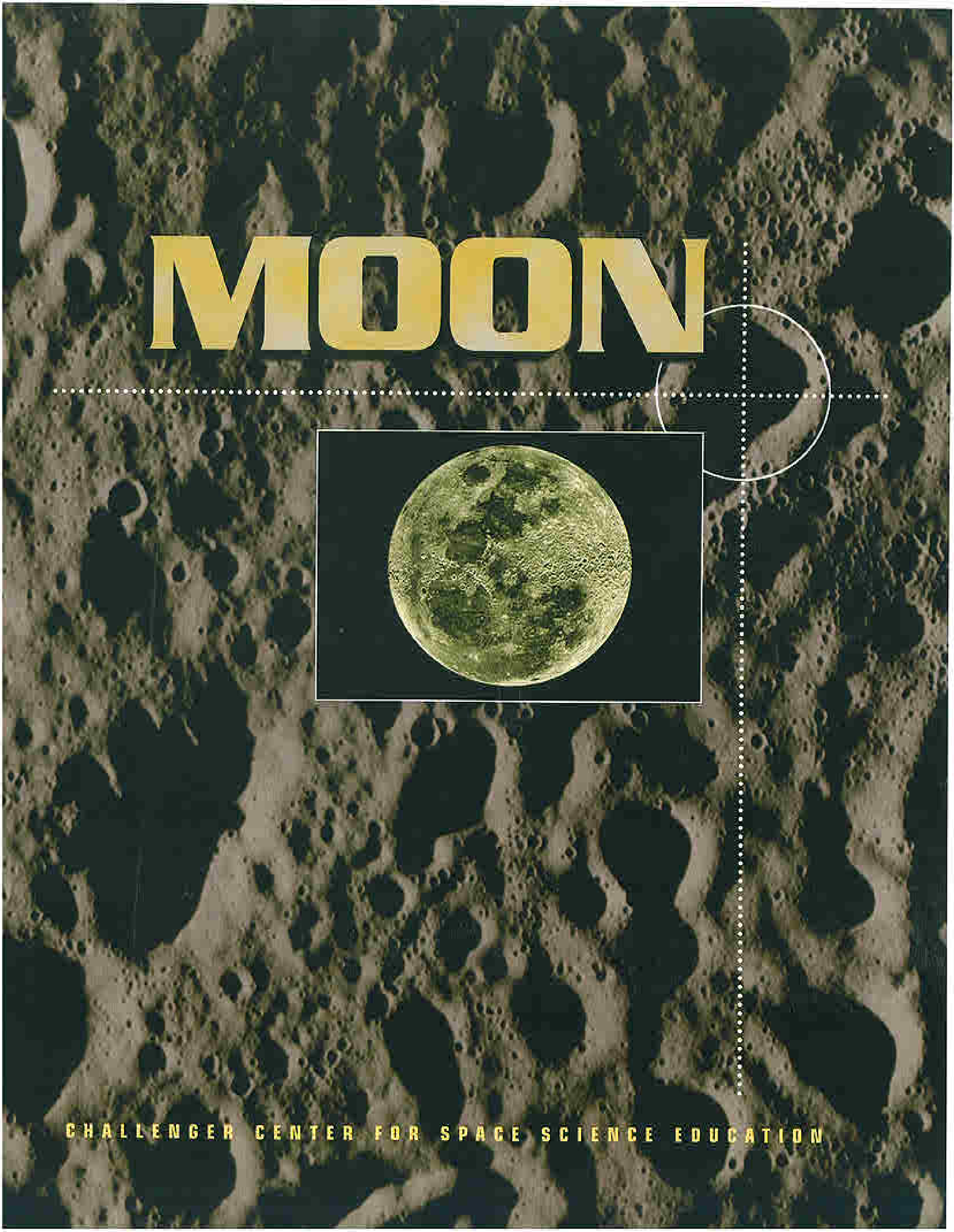
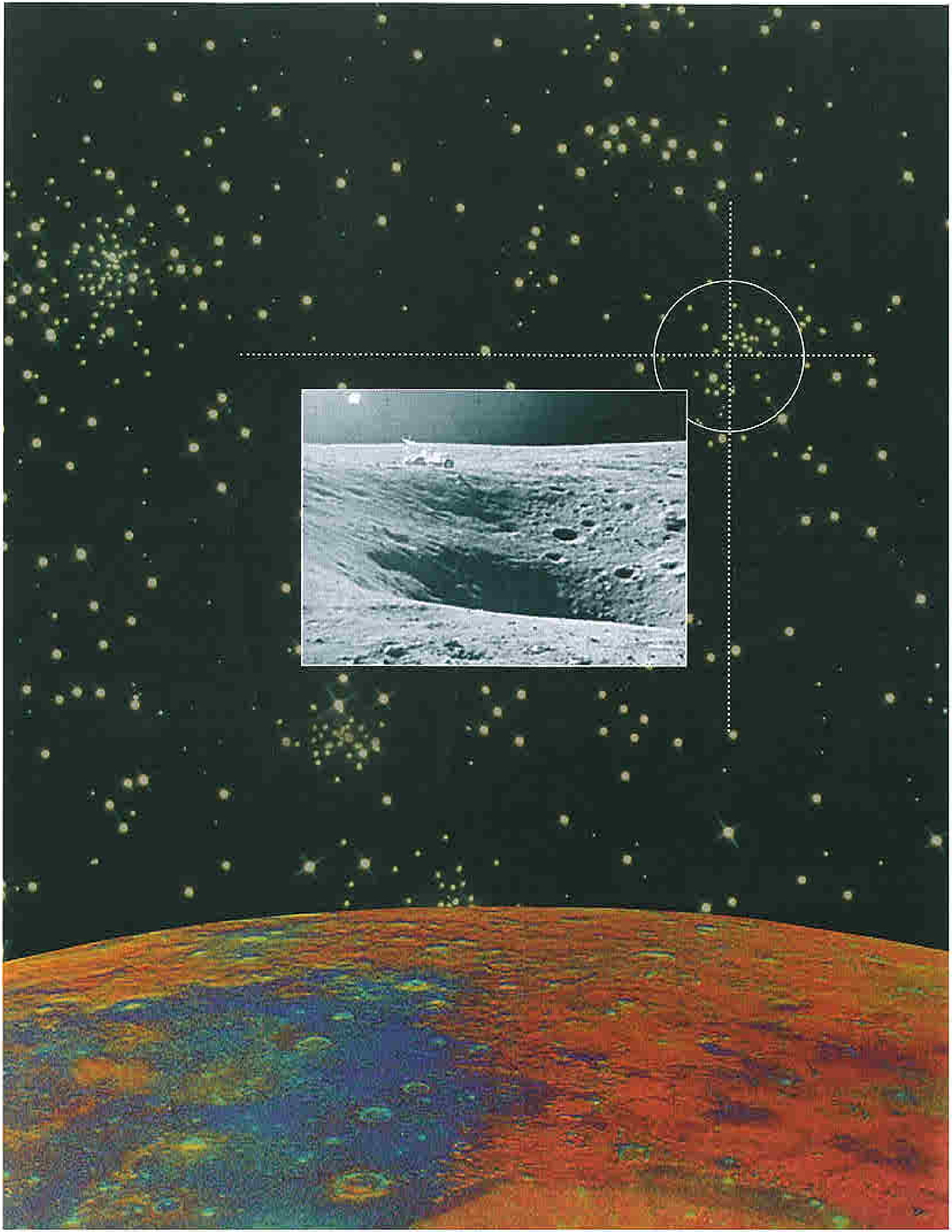
MOON



CHALLENGER CENTER FOR SPACE SCIENCE EDUCATION



MOON

A Teacher's Activity Guide

Another in the Series of
Challenger Learning EdVentures
from

Challenger
CENTER®

Table of Contents

Dear Educators iv

Challenger Center's Pedagogy and National Standards v

Moon vi

Moon Fact Sheet viii

Investigating the Moon: Pre-Activity Thinking Web ix

ACTIVITIES

Lunar Craters: 1
What are the characteristics of a crater?

Moon Phases: 7
Why does the Moon's appearance change as it revolves around the Earth?

Basic Life Support System: 11
What are the basic elements of a biosphere needed to create a balanced environment?

Lunar Geology: 19
How do geologists identify lunar rock samples?

Water on the Moon: 23
What obstacles do scientists face in attempting to extract water from lunar permafrost?

Distance to the Moon: 27
How far away is the Moon?

Extending The Mission 31

Glossary 32

Resources 34

About Challenger Center 37

Acknowledgements 38

Dear Educators

Dear Classroom Educator,

At Challenger Center we believe that in every young mind there is a window on the universe. Encourage that window to open and great things begin to happen. Young people become explorers. And we believe exploration is the essence of learning.

The key to opening that window and exploring new frontiers has to do with tapping a young person's natural curiosity. That curiosity is what powers the desire to ask questions and pursue answers.

To help teachers spark that curiosity, Challenger Center has assembled some of its most popular classroom activities into a series called *Learning Frontiers* using the popular space themes of Comets, Earth, Mars, and Moon. Studies have shown that space is one of the most popular and effective themes used to capture students' interest.

Since its founding in 1986, Challenger Center has used the theme of space to engage students in this pursuit, and has been nationally recognized for its innovative approaches to inspiring young people to explore. Challenger Center believes that when all is said and done, there are no tools, no programs, no techniques that will ever replace the direct intervention of a great teacher in a student's life.

That is why we hope you will find the *Learning Frontiers* activities engaging, relevant and—most of all—fun. These scientifically sound, educationally rich activities were developed to provide teachers with as much flexibility as possible when it comes to classroom implementation. To facilitate classroom use, teachers will find that each activity has been correlated to national education standards and is formatted to easily find objectives and key concepts.

We hope these activities will help you open your students' "windows" by using them to create new "learning frontiers" in a way that is appropriate for your classroom. Inspiring. Exploring. Learning. It's Our Mission.

Best Regards,
The Challenger Center Team

RETURN TO THE MOON®

In addition to being a great collection of classroom activities for any teacher to introduce the exploration of the Moon, this guide was designed to also help prepare students for Challenger Center's **Return to the Moon®** simulated mission when used with our **Mission Prep** guide. Hundreds of thousands of students "fly" simulated missions each year at Challenger Learning Centers throughout our international network. For more information visit www.challenger.org

Challenger Center's Educational Pedagogy

Challenger Center's educational pedagogy promotes scientific literacy by encouraging exploration and inquiry and exciting young people about knowledge and learning. Challenger Center believes exploration is the essence of learning. Our goal is to give teachers the tools to create a "learner-centered" environment and to provide materials that are a framework for embedding subject content in a meaningful and motivational context.

Using our interdisciplinary, inquiry-based approach that incorporates national educational standards, Challenger Center strives to:

- Increase student interest in science, mathematics, and technology.
- Give abstract concepts concrete meaning.
- Help students develop realistic processes of cooperation, communication, critical thinking, and problem solving.
- Increase student autonomy and responsibility for their own learning.
- Encourage students to develop positive perspectives about learning.
- Increase student commitment to learning.
- Help students pose questions and find pathways to answers.

Challenger Center programs are designed to reflect academic standards such as the National Science Education Standards by the National Research Council and the Curriculum and Evaluation Standards for School Mathematics by the National Council of Teachers of Mathematics.

Activity Matrix for National Science Education Standards and Curriculum and Evaluation Standards for School Mathematics (Grades 5-8)

	NATIONAL SCIENCE STANDARDS	Unifying Concepts and Processes	Systems, order, and organization	Evidence, models, and explanation	Change, constancy, and measurement	Evolution and equilibrium	Form and function	Science as Inquiry	Abilities necessary to do scientific inquiry	Understanding about scientific inquiry	Physical Science	Properties and changes of properties in matter	Motions and forces	Transfer of energy	Earth and Space Science	Earth's history	Earth in the Solar System	Science and Technology	Abilities of technological design	Understanding about science and technology	Science in Personal and Social Perspectives	Science and technology in society	History and Nature of Science	Science as human endeavor	Nature of science	History of science	NATIONAL MATHEMATICS STANDARDS	Mathematics as Communication	Mathematical Connections	Patterns and Functions	Algebra	Measurement
Lunar Craters				•	•		•			•		•	•	•								•			•							
Moon Phases			•	•	•				•	•			•				•			•				•	•	•		•	•			•
Basic Life Support System			•	•	•	•			•	•		•												•	•							
Lunar Geology			•	•	•		•		•	•		•													•							
Water on the Moon			•	•			•		•	•														•	•				•			•
Distance to the Moon			•	•	•		•		•								•								•							

Moon

The Moon is Earth's closest neighbor and only natural satellite. Revolving around the Earth at a nearly constant rate, the Moon provides a reliable means for measuring time. Present-day months are based upon this regular motion. As the Moon revolves around the Earth, it always keeps the same side facing the Earth. The half of the Moon that we see from Earth is illuminated by the Sun in varying amounts, causing the apparent shape of the Moon to change in the course of a month. The different apparent shapes of the Moon are called the phases of the Moon. While benign to humans, lunar phases play significant roles in the life cycles of some creatures. For instance, it appears that the spawning of some species of coral is regulated by the phases of the Moon.

The Moon's gravity, tugging on different parts of the Earth with different amounts of force, produces high and low tides in the world's oceans. Humans have harnessed this energy for centuries. In the 12th century, people used the movement of the water to turn water wheels at mills. Today, tidal power is generated in some areas by damming the mouth of a bay or estuary, allowing water to flow through a narrow opening as the tide rises and falls. Like hydroelectric dams in rivers, the flowing water drives turbines and electrical generators.

From Earth, the Moon appears as a bright disk of whites and grays. It is easy to distinguish dark and light patches on the surface with the naked eye. With a telescope, even more detail emerges. The dark patches, called maria (pronounced "MAR-ee-uh"), are relatively smooth plains, now understood to be made of solidified lava. The light areas are heavily cratered compared to the maria, a sign that they are a much older surface.

Overall, the Moon is very different from Earth. The surface is covered with lunar regolith, a fine-grained layer of rock fragments and dust formed by the constant rain of meteoroids. While the Moon has mountains, their height pales in comparison to terrestrial mountains. On the Moon there is no atmosphere to trap heat. That fact, combined with the month-long day-night cycle, leads to extreme temperatures ranging from 130° C (265° F) during the day to -110° C (-170° F) at night.

How did the Moon form? The preponderance of evidence now indicates that the Moon formed as a result of a giant impact on the Earth. Apparently, a Mars-sized object hit the Earth early in the Earth's history, after the Earth's iron core had formed. The impact ejected some of the rocky, iron-poor material from the outer parts of the Earth into orbit. This material collected together (because of its own gravity) to form the Moon.

Even before July 1969, when the Apollo 11 crew of Armstrong, Collins and Aldrin and a cast of thousands back at Earth orchestrated the first lunar landing, the Moon had been considered as a stepping stone to future, more distant explorations of the Solar System. The prospects of space exploration grew even larger in 1998 when a spacecraft orbiting near the Moon's poles hinted that water, which is crucial to long term missions, might lie frozen in the shadows of craters.

The Apollo visits to the equatorial regions of the Moon brought back the first lunar soil and rock samples for scientists to study. These samples always turned out to be bone dry. That, combined with the knowledge of the high temperatures on the surface, led most to believe that there was no water on the Moon. However, in 1994, the Moon-orbiting spacecraft Clementine beamed radio signals at the lunar surface. The beams that bounced back suggested that there may have been ice in a deep crater near one of the Moon's poles. Sunlight does not shine directly at the surface at the poles. As a result, craters have the ability to cast shadows that keep some areas on the Moon dark constantly, allowing for the possibility of a stable reservoir of ice. More evidence was gathered when, in January of 1998, a spacecraft called Lunar Prospector confirmed that there was a lot of hydrogen in the shadows of polar craters. It is believed by some that the source of this hydrogen is water.

What could water on the Moon do for us? It does not sound like a big deal, but it is a resource that could open up the possibilities of future space explorations. One reason that space travel is expensive is that people have to lug along everything they need to survive: oxygen, water, food, and fuel. Transporting water to the Moon would cost about $10,000 per pound of water. If a filling station was built on the Moon, people could stop off at the Moon to replenish their supplies, or possibly even stay on the surface for long periods of time. In addition, the elements that make up water—hydrogen and oxygen—are useful to humans. We, along with other animals, require oxygen to breathe. In fact, hydrogen and oxygen can be used as rocket fuel. By breaking down water into its fundamental elements, humans may be able to utilize this valuable resource even more.

Humans have been exploring the Moon for centuries. Galileo Galilei is often credited with the first scientific description of the Moon after peering through his homemade telescopes. Robotic exploration started in 1959 when probes from the Soviet Union's Luna spacecraft first impacted the Moon's surface. Spurred by a strong sense of competition between the United States and the Soviet Union, President John F. Kennedy stated in the early 1960s that he wanted to land an American on the Moon and safely return him to Earth by the end of the decade.

NASA immediately set to work on this challenging goal, first collecting information in the Mercury and Gemini projects. These projects placed America's first astronauts into space and Earth orbit, in addition to featuring the first American spacewalk and the execution of docking procedures. It also helped prepare astronauts for the Apollo program, which would see men orbiting the Earth, then the Moon, and finally landing upon the Moon. On July 20, 1969, Neil Armstrong stepped off the Apollo 11 spacecraft onto the rocky lunar surface, making history as the first man on the Moon.

The Apollo program brought twelve astronauts to land and walk on the lunar surface. While there, they collected lunar rocks and dust, drove over the surface in a vehicle called the rover, and even recovered a portion of a spacecraft sent by the U.S. to the Moon in 1967. Despite this extensive exploration—the only manned mission to worlds beyond Earth to date—astronauts explored only a small fraction of the surface. One idea for future exploration of the Moon is to send one or more rovers to investigate different areas on the Moon. But, many who are interested in the ongoing exploration of the Moon want to establish a permanent human presence on the Moon. Reasons for such a base range from mining on the Moon to using the base as a launching point for a manned mission to Mars.

FACT SHEET

Moon Fact Sheet

Distance from the Earth: Minimum: 363,300 kilometers
Average: 384,400 kilometers
Maximum: 405,500 kilometers

Eccentricity of Orbit: 0.055 (0.00 is a perfectly circular orbit)

Lunar Day (Length of Phase Cycle): 29.53 Earth days (709 Earth hours)

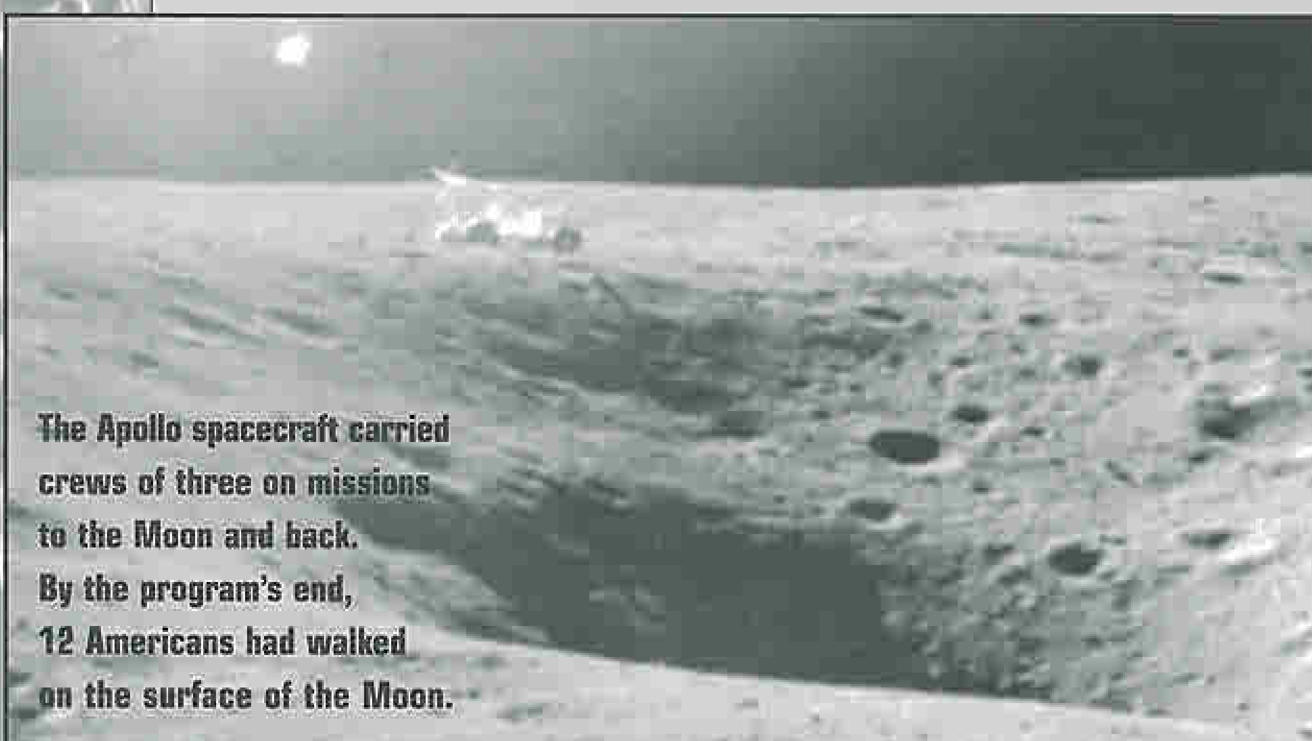
Orbital Period: 27.32 Earth days

Size: Diameter: 3,476 kilometers
Surface Gravity: 1/6 Earth's gravity
Mass: 7.4×10^{25} grams
Density: 3.34 grams/cm^3

Typical Range of Surface Temperature: -110°C (-170°F) to 130°C (265°F)

Atmosphere: No atmosphere

Surface: Two primary types of terrain: heavily cratered, old highlands and relatively smooth and younger maria.
Most of the surface is covered with regolith.
Largest impact basin in the solar system (South Pole-Aitken).
There is possibly water ice in deep craters at the north and south poles.
Lunar rocks recovered by Apollo astronauts were between 4.6 and 3 billion years old.



The Apollo spacecraft carried crews of three on missions to the Moon and back. By the program's end, 12 Americans had walked on the surface of the Moon.

Investigating the Moon

Objectives

Students will:

- Brainstorm and display key ideas.
- Explain their knowledge of the Moon.

Overview

Brainstorm and create a Thinking Web that demonstrates students' knowledge of the Moon. This is an opening exercise to introduce the study of the Moon to students and to assess prior knowledge.

Key Question

Why study the Moon?

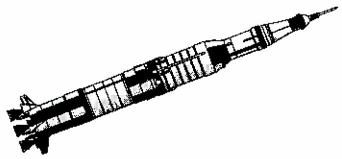
Procedures

1. Reproduce the student worksheet and give each student a copy.
2. Have students complete each question on the map and encourage them to draw illustrations to go with their answers.
3. You can use the students' answers as an informal method to assess prior knowledge by starting a class discussion. Students' answers will vary. Below are some examples of where to lead the discussion:

Examples of Student Responses	Discussion Points
The Moon changes appearance.	Discuss the phases of the Moon and the orbital motions that generate its change in appearance.
The Moon has a lot of craters.	Discuss what contributes to the comparatively large number of craters on the Moon's surface, such as lack of atmosphere and erosion.
The Moon has dark and light areas.	Talk about the maria and lunar highlands, and investigate why the smooth maria appear darker than the surrounding terrain.
People have walked on the Moon.	Talk about the Apollo space program and future plans to explore the Moon.
The Moon is the only natural satellite of the Earth.	Talk about the current theory of how the Moon may have formed.

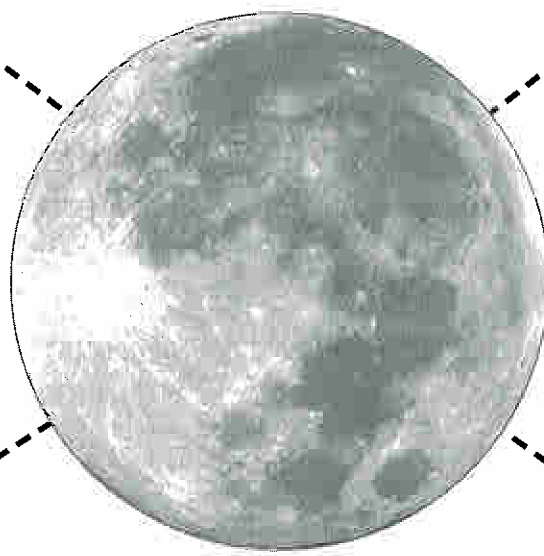
STUDENT WORKSHEET

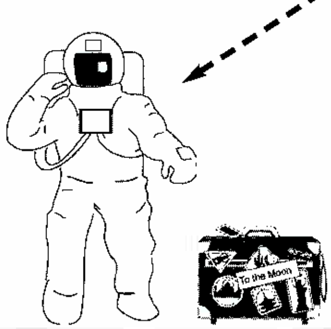
Investigating The Moon



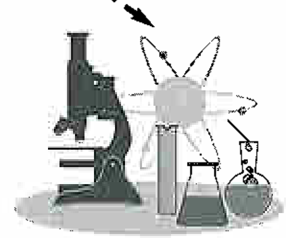
I know the Moon is . . .

I know the Moon has . . .





I would like to visit the Moon because . . .



If I went to the Moon I would study . . .

Lunar Craters

Background

Look at the Moon through a pair of binoculars, and you will see craters. Lots of them. In fact, it is hard to find any place on the Moon where there aren't any craters.

Craters are formed when meteoroids, small chunks of rock and metal that roam the Solar System, fall to the surface of a planet. The resulting impact forms a usually circular depression in the ground, which is called a crater. The base of a crater is called the floor, whereas the sides are called the wall. At the top of the crater wall is the crater's rim. When a meteoroid strikes a planet, debris is typically ejected from the site of the impact. This debris is called *ejecta*. Because the debris is ejected in streaks, rays are often observed surrounding a crater.

Because of the intense amount of energy involved, large impacts often cause the rock at the impact area to behave like a fluid. This causes many larger craters to exhibit a small, raised area in the center of the crater called a "central peak." It is not unlike the peak that is momentarily formed when a drippy faucet leaks onto a pool of water. In the case of craters, this peak solidifies, essentially frozen in time.

Craters on the Moon range in size from over 200 kilometers in diameter (larger than the state of Connecticut) to smaller than the head of a pin. Because there is no weather on the Moon, the only way to erode an existing crater is to cover it with more impacts or more debris from impacts. Young craters have sharp rims and are relatively deep. Older, more worn craters are usually more shallow and have less distinct rims. Scientists can estimate the relative ages of portions of the Moon by counting the number of impact craters present. The more craters, the longer the surface has been exposed to bombardment by meteoroids.

What you did in this activity is different than real cratering events in some ways. When a crater is formed on a planetary surface, the energy of the impactor can break apart—even vaporize—the impactor. In addition, crater size is determined by the energy of the impact, not the size of the impactor.

Topic

Craters

Objective

Students will:

- Evaluate and interpret the physical characteristics of a crater.

Overview

In this lesson students will simulate crater impacts by dropping pebbles or marbles into a pan of flour and cocoa. Students will identify the characteristics of lunar craters and compare them to the picture of a lunar crater.

Key Question

What are the characteristics of a crater?

Key Concepts

- Craters are depressions or pits formed by impacts.
- Craters have identifiable features.

Materials & Preparation

- Pie pans
- Pebbles or marbles
- Bags of flour
- Metric ruler
- Newspapers
- Powdered cocoa
- Meter stick

1. Divide students into pairs.
2. Ask students, "What are craters, and how are they formed?" Discuss with students the formation of craters and their features (rays, rim, ejecta, central peak).
3. Cover the floor with newspaper.
4. Fill pie pans with a thick layer of flour. Smooth out the flour so that it is as flat as possible.
5. Cover the top of the flour with a light dusting of cocoa (a sifter works well).
6. Have students place the pie pan on the floor or the ground.

7. Students will place one end of the meter stick on the floor and measure 30 cm above the pan.
8. Have students drop a pebble into the pan from the 30 cm height.
9. Students will then draw a picture of the crater that they have created on the student worksheet (do not have the students remove the pebble).
10. Have students repeat steps 7 through 9, creating the second impact in the pan so that it is not too close to the first impact.
11. Have students remove the pebbles, smooth the flour, sift on a new layer of cocoa, and repeat steps 7-10.
12. After students have drawn all four impacts give them the lunar crater image and have them label all the parts of their craters that they can identify in their drawings.

Management

One 50-minute class period.

Students must wear safety goggles when dropping the pebbles.

If corn starch is used instead of flour it will store longer and can be used again.

Reflection & Discussion

1. Discuss the features of craters with students.
2. Use the lunar crater image to show students how to tell the difference between older and newer craters.
3. Explain to students why ancient impact craters are still visible on the lunar surface today.

Transfer/Extension

1. Research crater impacts on Earth.

Lunar Craters

Student Procedures

1. Place the pie pan with the flour and cocoa on the floor or the ground.
2. Place one end of the meter stick on the floor and measure 30 cm above the pan.
3. Drop the pebble into the pan from the 30 cm height.
4. Carefully remove the pebble from the crater and draw a picture of the crater that you have created on the student worksheet.
5. Repeat steps 2 and 3 and create a second impact in the pan near the first impact. Carefully remove the pebbles from the crater and draw a picture of both craters on the student work sheet.
6. Refill the pan, sift on a new layer of cocoa and repeat steps 2-5.
7. After you have drawn all four impacts, use the Crater Fact Sheet and label all the parts of your craters.

Questions & Conclusions

1. How did the appearance of the surface of the flour change after it had been impacted?
2. What does the cocoa reveal about how impacts change the surface?
3. Describe the features of each of your craters.
4. Compared to the Crater Fact Sheet, was your model an accurate representation of lunar craters? Explain why or why not.

Impact Crater Fact Sheet

What is an Impact Crater?

Impact craters are marks found on every solid body in the Solar System, like planets and moons. Even asteroids are pitted with craters. When an object slams into a planet, it hits the surface very hard and explodes. Rocks and dust fly everywhere. The object that hits the planet is called an impactor. The impactor breaks apart because of the force of the impact, and the impact explosion leaves a round hole or crater in the surface of the planet.

Crater Parts

Walls–The sides of the bowl. Walls can be very deep. They may look like steps, or walls can be shallow. If a crater has shallow walls, then the hole was filled or eroded somehow.

Floor–The bottom part of the impact site (the hole). It may be the shape of a bowl, or it may be flat. This part is lower than the surrounding surface.

Rim–The highest point along the edge of the hole.

Ejecta–The debris that shoots, or ejects, out of the impact site when the crater forms. There is a lot of ejecta close to the crater, so it is thick. The ejecta gets thinner the farther away it is from the crater. The explosion creates debris as it crushes, heats and melts the rock.

Rays–The bright streaks that start at the rim of the crater and extend outward.

Central Peak–A small mountain that forms at the center of the crater in reaction to the force of the impact. Only really large craters, typically more than 40 km across, can have a central peak. These craters are the size of large cities.

What Changes the Shape of a Crater?

Initially, craters have a crisp rim and blankets of ejecta around the sides. On the Earth, actions of wind, water, lava flows and plate tectonics can alter the appearance of a crater. Wind can blow away debris around the crater. Rivers and floods can erode the crater's walls and rim. On the Moon, lava flows can fill in the crater and make the rim smoother. Another impactor may come along and give the crater its own crater. Other impactors can partially or completely destroy an older crater.

Craters and Surface Age

The older a surface is, the more time impactors have to hit it. Really old surfaces have so many craters that it would be difficult to tell if another impactor hit it. Little of the surface is smooth. Most cratering took place right after the planets and moons formed. Places like the Earth's Moon and the planet Mercury have heavily cratered, old surfaces.

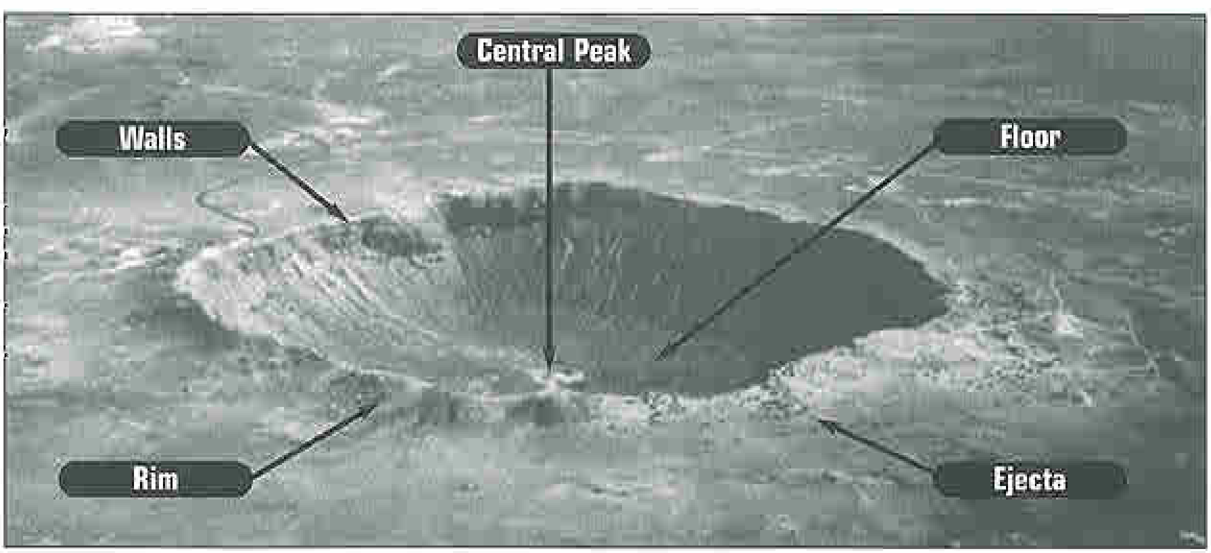


Image courtesy of NASA

Crater #1

Craters #1 & #2

Crater #3

Craters #3 & #4

Moon Phases

Background

Watching the night sky, primitive civilizations believed that the Moon actually changed shape over the course of a month. These changes in apparent shape are known as the phases of the Moon.

Like all of the other planets in the Solar System, only one-half of the Moon can receive sunlight at a given time. As the Moon revolves around Earth, its appearance changes from day to day, depending upon its location in orbit. Sometimes the sunlit side of the Moon is facing away from Earth. This is referred to as the *New Moon.* During the New Moon, the Moon cannot be seen from Earth with the naked eye because the dark side is facing us and because you would be looking toward the Sun. The New Moon rises near the time of sunrise and sets near sunset.

When the sunlit side of the Moon faces Earth, a Full Moon is seen. For this to occur, the Moon must rise and set opposite the Sun. Therefore, when the Sun is setting in the evening (say, about 6:00), the Full Moon is rising in the east. Use the diagram to see why this must be the case.

In between the New and Full Moons, when only half of the side facing the Earth is illuminated, First and Third Quarter Moons are said to be seen. First and Third Quarter Moons get their name from their orbital "stage." If the New Moon is the beginning of the orbital cycle, then the Moon has completed one-fourth of its cycle at First Quarter. The Full Moon is halfway through the cycle. Three-quarters of the way through the cycle the Third Quarter Moon is seen. The end of the cycle is also the beginning of a new one—the New Moon. Again, use the diagram to help you visualize how this works.

Between New Moon and First Quarter, only a small part of the illuminated side of the Moon is visible from Earth. This is a *Crescent* Moon. We also see a Crescent Moon between Third Quarter and New Moon.

Between First Quarter and Full Moon, the Moon appears more than half full, but not completely full. This is a *Gibbous* Moon. The Moon also appears gibbous between the full and third quarter phases

Between New Moon and Full Moon, when the Moon is becoming more and more full, the Moon is said to be *waxing.* Between Full Moon and New Moon, when the Moon is becoming less and less full, the Moon is said to be *waning.* So, starting with New Moon, the Moon waxes during the first half of its orbit and wanes during the second half of its orbit.

A more tangible way of appreciating the cause of the phases of the Moon is to make a model, using a light bulb for the Sun and tennis balls for the Earth and Moon.

Topic

Moon Phases

Objectives

Students will:

- Explain the phases of the Moon through modeling.
- Observe how the Moon's phases change.

Overview

In this activity students will use a model to demonstrate the phases of the Moon and use the given diagrams to verify their models.

Key Question

Why does the Moon's appearance change as it revolves around the Earth?

Key Concept

- To model the phases of the Moon and determine why we see each phase.

Materials & Preparation

- One tennis ball (paint 1/2 black)
- Student worksheets

1. Divide the class into groups of two.
2. Give one student a tennis ball while the other sits in a chair facing the front of the class. The front wall of the class is the Sun.

3. The student with the tennis ball walks in a circle around the other student, stopping at eight even intervals of 45 degrees.
4. As they walk in a circle the student holding the tennis ball positions the ball with the painted black surface facing away from the front wall (Sun).
5. The seated students draw on the student worksheets a picture of the ball exactly as they see it showing as much of the light and dark sides as is visible at each of the eight locations.
6. Give students the phases of the Moon diagram to verify their work.

Management

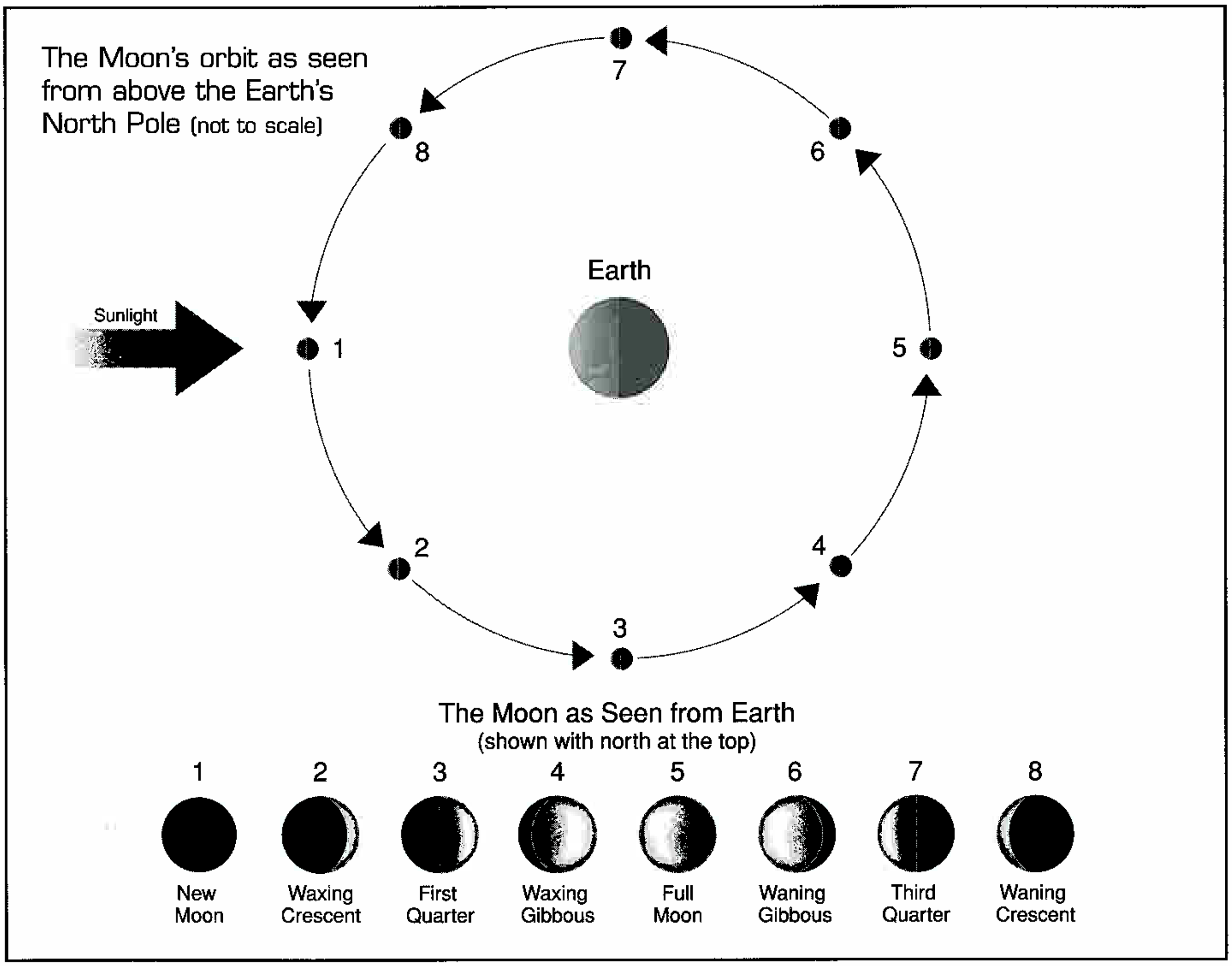
- One 50-minute class period.
- Students should work in groups of two.

Reflection & Discussion

1. What do the terms waxing and waning mean?
2. Are there special meanings to the terms gibbous and crescent?

Transfer/Extension

1. Have students research and write a report about the history of using the Moon to tell time.



Students will use this diagram to verify their work.

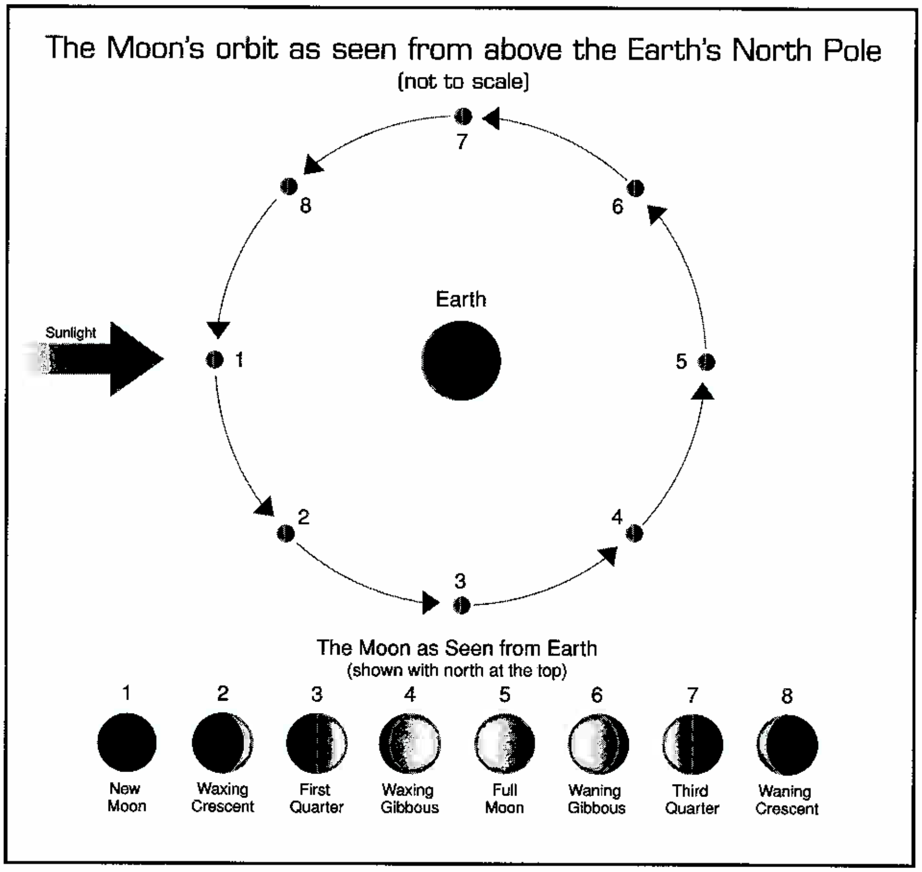
Moon Phases

Student Procedures

1. One student takes a tennis ball while the other sits in a chair facing the front of the class. The front wall of the class represents the direction of the Sun, and the source of light.
2. The student with the tennis ball walks in a circle around the other student, stopping at eight even intervals of 45 degrees.
3. At each stop, the student holding the tennis ball positions the ball with the painted black surface facing away from the front wall (Sun).
4. The seated student draws on the student worksheet a picture of the ball exactly as they see it, showing both the light and dark sides as much as each is visible.
5. Look at each drawing and try to name each of the Moon phases.
6. Use the phases of the Moon diagram to verify your work.

Questions and Conclusions

1. What do the terms waxing and waning mean?
2. Are there special meanings to the terms gibbous and crescent?
3. Do your drawings look like the ones on the Phases of the Moon diagram? Why/or why not?



Position #1	Position #2

Position #3	Position #4

Position #5	Position #6

Position #7	Position #8

Basic Life Support System

Background

If you look into a terrarium, you can see a mini-biosphere. In order for life to survive, there must be a balance between organisms and the system in which they live. Earth is the ultimate example of this. It holds and sustains all of the processes needed for life as we know it. For example, plants require light (supplied by the Sun), nutrients (supplied from the soil—usually as byproducts of waste from living organisms) and carbon dioxide for growth, while giving off oxygen as a byproduct. Humans and other organisms benefit by taking in oxygen to survive and releasing carbon dioxide that is used by the plants. Life has existed on Earth for so long because of mutually beneficial relationships such as these. The fact that life is supported on Earth seems to make it unique in the Solar System. There is not a comparable atmosphere elsewhere in the Solar System that can maintain the careful balance that Earth organisms need. This is a great concern as humans consider traveling and living beyond Earth's atmosphere.

The Moon is the Earth's closest neighbor. Its proximity has allowed us to study it extensively and to successfully land humans on its surface, yet, it is extremely different from Earth in many ways. The heavily cratered surface is covered with a material unlike the nutrient-rich soils which are familiar to us. The Moon lacks an atmosphere, which would make it difficult for an Earth organism to survive. Although there is recent evidence of water ice on the Moon, it has only been found only in the permanent shadows cast by craters at the north and south polar regions. Only there does it remain permanently cold. Water ice exposed to typical daytime temperatures on the Moon would rapidly sublimate into water vapor and escape to space. While the potential discovery of water ice on the Moon is exciting—providing a possible source of water and oxygen for a future lunar base—it may be difficult to harvest. It is found deep in polar craters and is likely frozen within the lunar soil.

The discovery of the possible presence of water has renewed interest in further lunar exploration missions and establishing a long-term human presence on the Moon. This would require constructing a basic Life Support System, because of the differences between the environments of the Earth and Moon. This system would need to be self-sustaining in order to ensure survival of the organisms that would inhabit it. Humans and other organisms will continue to need food, water and air. These basic requirements will be imported initially, but this is expensive, so it is imperative that the Life Support System be able to support itself. Increases in crew size or mission duration must also be taken into account. It would be preferable to regenerate necessary materials, rather than rely on resupply missions to meet crew life support requirements. Systems will need to be developed to produce food, purify water supplies and regenerate oxygen from expelled carbon dioxide. A life support system that would perform these regenerative functions has been called a Controlled Ecological Life Support System (CELSS). A CELSS is a tightly controlled system, using crops to perform life support functions, under the restrictions of minimizing volume, mass, energy and labor.

Topic

Basic Life Support System

Objectives

Students will:

- Determine the basic elements required to sustain life.
- Construct a biosphere model to better understand the concept of basic Life Support Systems.

Overview

Conditions in space and on planets in our Solar System are not favorable for sustaining life. These environments cannot provide all the essential things we need to live: water, food, and oxygen. In this activity, students will construct a self-contained, balanced biosphere.

Key Question

What are the basic elements of a biosphere needed to create a balanced environment?

Key Concepts

- The Earth's biosphere has a unique, complex system of balance that allows life to survive.
- A biosphere is successful when it is balanced, self-enclosed, and able to function efficiently over a long period of time.
- Efficient, long-term human presence in the harsh environment of the Moon would require a regenerative Life Support System.

Materials & Preparation

- Data and observation sheet
- Measuring cups and spoons
- Assorted soils and sand
- Fertilizer
- Seedlings
- Water
- Clear plastic tape
- Lamp
- Two 2-liter bottles
- Small, living organisms (such as insects) —optional

1. After discussing the background and purpose of this activity, divide the class into cooperative teams of four. Assign the following roles within each team:
   - **Botanist:** person who studies plants
   - **Soil Specialist:** person who studies condition of soils
   - **Science Specialist:** coordinates interaction between all aspects of the biosphere model including soil, plants, water, and light
   - **Entomologist (optional):** person who studies insects
2. Have teams brainstorm and list all of the elements from Earth needed to create a balanced biosphere model on the Moon. Have them consider what they could harvest from the Moon's surface to include in the biosphere model.
3. Distribute the Student Worksheets. Students are responsible for reading and sharing data contained on their worksheets. Have students log their shared information on their worksheets.
4. Each team should decide, based on the recommendations given on their Student Worksheets: soil (best mixture and amount of each soil type); kinds and amounts of plants; optimal water amount prior to sealing; and optimal lighting (direct Sun, shade, artificial light).
5. After each team has discussed and decided on the content of its biosphere model, let each student build his or her own according to the team plan. The biosphere model must be completely sealed with clear tape. No air or other materials can go in or out. Once the biosphere model is sealed, it cannot be opened again.
6. Each biosphere model should be set under the lighting conditions chosen by the team—remember that this will be determined by their location on the Moon.
7. Have students label their biosphere model with their names, names of their team members, date, and time sealed.
8. Assign students to complete data and observation sheets daily, or on a basis that works best for your class.

Management

Seedlings: About 2 weeks prior to the activity, sprout seedlings for use in the biosphere model. Successful ones have been made using mung, radish, and peanut plants, as well as simple garden weeds. Seedlings can be purchased at a local garden center.

Soil Material: Collect a variety of soil materials such as vermiculite, permiculite, cinder, gravel, sand, silt, and clay.

Animals (optional): Students should collect live critters such as caterpillars, ants, worms, etc. to live in the biosphere model. We recommend that they are collected on the day of biosphere model completion to ensure that they are well cared for. Most pet stores sell a wide variety of live insects and worms. **If animals are not used, students should be made to understand that the cycle is not complete. Carbon dioxide will not be supplied to plants from living organisms and the plants will not survive after their supply of carbon dioxide is depleted.**

Biosphere Model: Use two 2-liter plastic bottles. Remove the labels. Cut off the top 8.5 cm from the first bottle. Cut the second bottle 7.5 cm from the bottom. Students will take the two pieces and put them together as in diagram A. Have enough materials for each student to make one biosphere model.

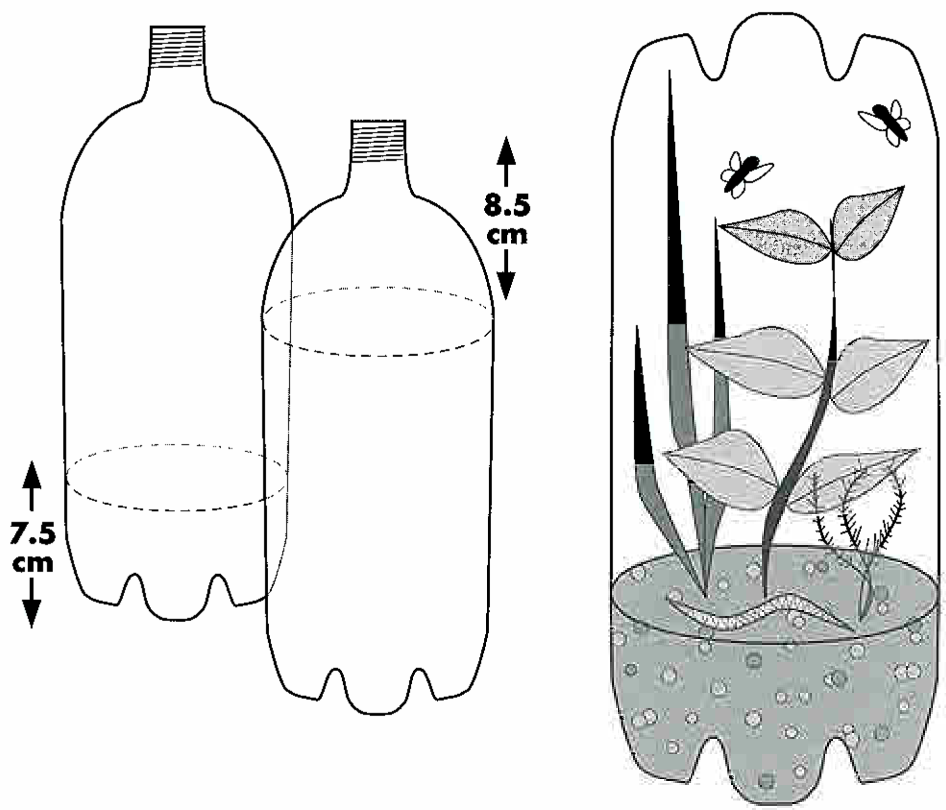
Reflection & Discussion:

1. Are some of the biosphere models doing better than others? Why or why not?

Transfer/Extension

1. Compare your self-contained biosphere to life support conditions needed for the Moon.
2. Look for examples of NASA research being done in closed environments, such as Bioplex at Johnson Space Center and write a report about them. http://pet.jsc.nasa.gov
3. Research how the conditions of your biosphere model might change if humans are introduced into it.
4. Research what other harsh environments exist, in addition to the Moon, where a Life Support System would be necessary for human survival.

Diagram A



Basic Life Support System

Student Procedures

1. Fill out the "Materials Used Data Sheet" with your team's choice of soil mixture, type and number of seedlings and other organisms, optimal lighting conditions, and the optimal amount of water to add to the biosphere before sealing. Remember that you are trying to create a living system that will remain balanced over a long period of time.
2. Obtain a pre-cut plastic bottle from your teacher and build your personal biosphere following the team's recommendations.
3. Seal your biosphere model with clear plastic tape. Once it is sealed, no air or other materials can go in or out. After the biosphere model is sealed it cannot be reopened.
4. Label the biosphere model with your name, the names of your team members, and the date and the time it was sealed.
5. Set your biosphere model under the lighting conditions chosen by your team.
6. Fill in the "Basic Life Support System Observation Sheet" as directed by your teacher.

Botanist

Recommendations: You should try to find a hardy plant that still may survive in less-than-perfect conditions. Also, if plant-eating animals are being placed in the biosphere, it may be helpful to provide a variety of plant species so that you can better ensure that there will be an acceptable food supply. Garden weeds may work well. Other specific types of plants may include:

- Mung bean, *Phaseolus aureus*—The mung bean grows 76-90 cm tall and has many branches with hairy bean like leaves. Flowers are yellowish-green with purple streaks and produce long, thin, hairy pods containing 9-15 small yellow seeds. Seeds are used to produce bean sprouts.
- Radish, *Raphanus sativus*—Radishes produce white, red, or black roots and stems under a rosette of lobed leaves. Radishes should be planted 1 cm deep and will sprout in 3-7 days.
- Peanut, *Arachis hypogaea*—The peanut belongs to the pea family and grows from 15-76 cm tall. Flowers are small yellow clusters that grown on stems called pegs. Pegs grow downward and push into the soil. Nuts develop from these pegs 3-8 cm underground.

Considerations: For the plants above and for any other plants, you need to consider the following questions.

- What is the best soil type for this plant?
- How much water does the plant require?
- What are the best lighting conditions?
- How tall and fast will the plant grow?
- Will the animals eat this plant?

Soil Specialist

Recommendations: Soil supplies water, nutrients, and gases, as well as structural support to plants. The ideal soil for a biosphere model should hold moisture and nutrients while letting excess water drain to make room for air. There are many types of soil. The following are some examples:

- Clay: Small particles, less than 1/250 mm, which pack closely; clay has poor drainage. However, clay often contains high levels of nutrients and can hold moisture fairly well.
- Sand: Irregular particles between 1/16 mm and 2 mm; sand drains well and is easy to manage, but has a low nutrient content.
- Loam: A mixture of both sand and clay, loam usually drains well and has a high nutrient content, although too much rain can turn it lumpy and a little difficult to handle.

Considerations: When mixing and layering soil, you need to consider the following questions.

- How well does it hold water?
- What is the nutrient content?
- Does it provide structural support for plants?
- How well does it drain excessive water?

Science Specialist

Recommendations: A balanced biosphere model should provide soil, light, oxygen, water and food for living organisms.

- Soil provides nutrients to the plants.
- Plants provide oxygen and sometimes food for living organisms.
- Water is necessary for both plant and animal life. However, too much water can cause plants to rot.
- Light is needed for plants to grow, although different plants require different amounts of light. Too much direct light can burn plants.
- If animals are used, it is important to consider the balance between the amounts of plants and animals. For instance, if you have too many plant-eating animals, they may eat all of their food supply, thus leaving them without food and a means to recycle carbon dioxide into oxygen.

Considerations: When working with your team, you should consider the following questions.

- Are there enough nutrients in the soil for all the plants?
- Is there enough water?
- Is the lighting condition appropriate?
- Does the biosphere model include food for the animals in amounts that will be supportive, not destructive?

Entomologist (optional)

Recommendations: There are a wide variety of insects you can use in your biosphere. However, each insect has its own needs in terms of diet and environment. Here are some examples:

- Ladybugs are commonly known as beneficial insects. Ladybugs eat aphids, which are small bugs that are destructive to plants. A ladybug's life cycle depends on temperature, humidity and food supply.
- Ants eat worms, spiders, and other insects. Areas with red ants have lower infestations of pests. Ants generally burrow and live underground.
- Cockroaches like dark, moist areas with temperatures around 25° C. Cockroaches will eat nearly anything. If a cockroach is in a cardboard or plastic container and there isn t any food, it will start to eat the container.

Considerations: For the insects above, or any others you choose, you need to consider the following.

- What does the insect eat?
- Where do they live?
- What kind of climate are they used to?
- Does the insect need shade or direct sunlight?

Basic Life Support System

Materials Used Data Sheet

Name: ____________________

Date: ____________________

Soil Material	Amount Used—Explain Why

Seedlings and Insects	Amount Used—Explain Why

Lighting Conditions—Explain Why	Amount of Water Added—Explain Why

Date and time it was sealed: ____________________

Basic Life Support System

Observation Sheet

Name: ______________________________

Date: ______________________________

Date	Lighting Conditions	Plants	Insects	Observations	Color Sketches

Questions & Conclusions:

On a separate sheet of paper, summarize the success or failure of your biosphere model. Be sure to address the following question:

Are some of the biosphere models doing better than others? Why or why not?

Lunar Geology

Background

Geologists are scientists who study the formation, structure, history, and processes (internal and on the surface) that change Earth and other planetary bodies. Rocks and the minerals that they are composed of give geologists key information about the events in a planet's history. By collecting, classifying, and analyzing rocks, we can learn how they were formed and what processes have changed them.

Geologists classify rocks into three general types:

- **Igneous -** rock formed when magma cools and hardens either below the surface (a common example of this is granite), or on the surface during volcanic events (for example, basalt).
- **Sedimentary -** rock formed by the collection, compaction, and cementation of eroded mineral grains, rock fragments, and sand (for example, sandstone and shale).
- **Metamorphic -** rock formed when heat and/or pressure deep within the planet changes the mineral composition and grain size of existing rocks (for example, metamorphism changes limestone into marble).

Geologists can further identify rocks by determining their mineral composition. Depending on the amounts and types of minerals found in a rock sample, a rock may be classified in a number of different categories. The mineral composition can also give scientists clues as to where and how the rock was formed.

The Moon's surface is dominated by igneous rocks. The lunar highlands are formed of anorthosite, a light-colored igneous rock with visible grains. It is by far the most common type of rock on the surface of the Moon. The lunar maria are made of layers of basaltic lava, not unlike the basaltic flows of the Columbia River Plateau in the northwest part of the United States. Breccias, which are made of rock and mineral fragments that have been fused together by the heat of meteoroid impacts, are also common on the surface.

Topic

Lunar Geology

Objectives

Students will:

- Investigate and identify mineral content in simulated lunar rocks.
- Investigate and identify simulated lunar rocks based on mineral content.

Overview

Students will cut cross sections of simulated lunar samples to determine the mineral content. Using this information students will identify different types of lunar rocks.

Key Question

How do geologists identify lunar rock samples?

Key Concept

- Rocks can be identified by the percentage of minerals that make up each sample.

Preparation & Materials

- Two packages of clay
- Sewing beads:

  white, (longer than wide) for plagioclase

  brown, (almost square) for pyroxene

  green, (almost round) for olivine

  black, (almost square) for ilmenite (optional for activity extension)
- Nine small air tight containers
- Floss, thin wire, plastic knives, or any other apparatus for slicing clay samples
- Masking tape

1. To make an anorthosite sample, count out 360 white beads, 20 brown beads and 20 green beads. Knead these beads into a ball of clay. Divide this thoroughly mixed clay into thirds. Place these mock lunar samples into an air tight container. Using the masking tape and a marker, label the container with a number. Record the

number and note on a piece of paper that this number represents anorthosite.

2. To make a norite sample, count out 240 white beads, 140 brown beads and 20 green beads. Knead these beads into a ball of clay. Divide this thoroughly mixed clay into thirds. Place these mock lunar samples into an air tight container. Again, label the container with a number and, for future reference, record the number and rock type.
3. To make a troctolite sample, count out 240 white beads, 20 brown beads and 140 green beads. Knead these beads into a ball of clay. Divide this thoroughly mixed clay into thirds. Place these mock lunar samples into an air tight container. Again, label the container and record the rock type on your answer key.
4. Scientists use a thin slice method to identify a rock. The crystals on the surface of the slice are classified and then the amount of each mineral is determined. A rock is then identified by the percent of each crystal found in the sample. Have each student take one of the mock lunar samples and record the letter of the rock sample on a separate piece of paper. This paper will be their data sheet.
5. Have the students gently slice the sample in half. Using the information given in the Lunar Geology Student Worksheet, have students determine the mineral crystal that is represented by each of the beads. Have them count the number of each type of crystal (beads) and record that number on the data sheet. Each side of the split mock lunar sample is considered a thin slice.
6. The students should repeat step 5 two times, kneading the clay together in between slices.
7. Have the students calculate the average amounts of beads in each sample. Have them record their calculations and answers.
8. Use the averages to have the students calculate the percentages of beads in each sample. Again, record the answers.
9. Repeat steps 4-7 for the remaining two samples.
10. Using the percentages given in the student fact sheet, have the students identify the types of rocks provided. You may check their answers with the answer key you created.
11. Have the students complete the Question and Conclusion portion of the worksheet.

Management

- Divide students into cooperative groups
- Three 50-minute class periods
- Make the clay samples before the activity is to be performed.
- When purchasing beads, avoid those which are covered with a thin layer of paint (such as a metallic or opalescent bead). The paint tends to shed when it is in the clay, and makes it difficult to differentiate between the paint and the actual beads.
- Review how to calculate percentages and averages before beginning this activity.

Reflection & Discussion

1. Could we have done this sort of rock identification to Moon rocks before the Apollo missions? Why or why not?
2. Did you always count the same percentage of minerals in every slice you took of a given sample? Did you ever get the exact percentage that was given in the student worksheets? Is science always exact?

Transfer/Extension

1. With the remaining clay, beads, and the optional black beads, make up samples of the mare basalts. (To make a high-titanium sample, use 72 black beads, 12 green beads, 216 brown beads, and 120 white beads.) Using the data table, have the students try to classify this new rock.
2. Arrange to go to a local college or university with a geology department. Ask to see examples of the equipment used to identify rock types, and also to look at rocks that resemble those found on the Moon.

Lunar Geology

Student Procedures

1. Scientists use a thin slice method to identify a rock. The crystals on the surface of the slice are classified and then the amount of each mineral is determined. A rock is then identified by the percent of each crystal found in the sample. Take one of the mock lunar samples and record the letter of the rock sample on a separate piece of paper. This paper will be your data sheet.
2. Gently slice the sample in half. Using the following table, determine the mineral crystal that is represented by each of the beads:

MINERAL	ELEMENTS	APPEARANCE IN MOON ROCKS
Plagioclase feldspar	calcium (Ca), aluminum, silicon (Si), oxygen (O)	Off-white to translucent grayish; usually occurs as grains longer than they are wide.
Pyroxene	iron (Fe), magnesium, (Mg), calcium (Ca), silicon (Si), oxygen (O)	Brown to black; grains usually longer than wide in mare basalts, almost square in highland rocks.
Olivine	iron (Fe), magnesium (Mg), silicon (Si), oxygen (O)	Greenish; usually occurs as almost round crystals.
Ilmenite	iron (Fe), titanium (Ti), oxygen (O)	Black, elongated to almost square crystals.

Count the number of each type of crystal (beads) and record that number on the data sheet. Each side of the split mock lunar sample is considered a thin slice.

3. Repeat step 2 two times, kneading the clay together in between slices.
4. Calculate the average amounts of beads in each sample. Record your calculations and answers clearly on the worksheet.
5. Use the averages you found to calculate the percentages of beads in each sample. Again, record the answers.
6. Repeat steps 1-5 for the remaining two samples.
7. Using the following percentages, identify the types of rocks provided.

Mineral abundance (percent) in Moon rocks

	Plagioclase	Pyroxene	Olivine	Ilmenite
Highland rocks				
Anorthosite	90%	5%	5%	0%
Norite	60%	35%	5%	0%
Troctolite	60%	5%	35%	0%
Mare basalts (transfer/extension project)				
High-titanium	30%	54%	3%	18%
Low-titanium	30%	60%	5%	5%
Very low-titanium	35%	55%	8%	2%

8. Complete the Questions and Conclusions portion of the worksheet, writing down your answers on your data sheet.

Questions & Conclusions

1. This process represents one way to classify rocks. Can you think of any other ways scientists might use to try to classify rocks? What are the advantages or disadvantages of each? Is there a disadvantage to this method?
2. Why do you think that you took the average of several rock slices? Do you think it would have been better to take more, or just as effective if you took less? Why?

Date Taken: 02/06/71
Title: View of large boulder found by Apollo 14 crew

This is one of the white rocks from which samples were taken by the astronauts of the Apollo 14 lunar landing mission.

Image courtesy of NASA

Water on the Moon

Background

On March 5, 1998, it was announced that data returned by the Lunar Prospector spacecraft suggested water ice is present at both the north and south lunar poles. If these reports are confirmed, near-pure water ice may be present in discrete, confined deposits buried beneath as much as 18 inches (46 centimeters) of dry regolith. The discovery could open a number of interesting options for future explorations of space.

Because the Moon has no atmosphere, any substance on the lunar surface is exposed directly to the vacuum of space. Over the course of a lunar day (~29 Earth days), nearly all regions of the Moon are exposed to sunlight, and the temperature on the Moon in direct sunlight is high enough that water ice will rapidly sublime directly into water vapor and escape into space, as the Moon's low gravity cannot hold gas for any appreciable amount of time. Any ice exposed to sunlight for even a short time would be lost. The only possible way for ice to exist on the Moon would be in a permanently dark area, such as in the shadow of a crater.

The presence of water on the Moon could open up a number of valuable options for those who would endeavor to explore other planets. Because astronauts need to carry large quantities of water with them for their survival in space, great amounts of rocket fuel—which is typically expensive—are needed to overcome the force of Earth's gravity. Also, the elements that make up water (hydrogen and oxygen) can be used as rocket fuel itself. If water could be mined at the Moon's surface, where the force of gravity is only a fraction of what it is on Earth, large amounts of money could be saved. For example, manned missions could stop at the Moon before travelling to Mars or another distination. The resource might also be used to sustain a colony of people on the lunar surface.

Topic

Lunar Water

Objectives

Students will:

- Construct a solar water collector.
- Estimate the amount of water in a given sample of simulated lunar permafrost.

Overview

In this activity students will construct a solar water collector. Using the collector, students will collect and calculate the amount of water in an area of simulated lunar permafrost. Students will evaluate the pros and cons of using this system on the Moon.

Key Question

What obstacles do scientists face in attempting to extract water from lunar permafrost?

Key Concept

- Scientists must design and evaluate many ways of extracting water from the lunar permafrost before planning lunar colonies.

Materials & Preparation

- Cake pan or tray (approximately 9x12 inches, and at least 3 cm deep)
- Fine-grained sand, such as sandbox sand
- Plastic wrap
- Water
- Washers or pennies
- Access to a freezer
- Heat lamp
- Small paper cup
- Graduated cylinder
- Clock
- Tape

1. Prior to class put 600 ml of the sand into the pan. Pour 100 ml of water into the pan of sand. Prepare one pan for each group of

students. Place pans of sand into the freezer and leave until frozen solid.

2. Discuss with students the significance of finding water on the Moon. Think about how this water could be helpful, and allow them to start considering ways they might extract it.
3. Explain to the class that they will be making a scale model of a water extractor that might work well on the Moon.
4. Give each group of students a pan of simulated frozen lunar regolith and have the students place the paper cup in the center of the tray. If the cup is taller than the side of the tray, have the students trim the cup so that it sits about 2 cm lower than the side of the tray.
5. Have students seal the top of the tray with plastic wrap. Have them seal and secure the plastic wrap over the tray with tape so that, when weighted with the washers, it droops slightly. However, the plastic should not be so loose that it touches the rim of the cup. You may wish to walk around the class and ensure that the collectors are set up properly.
6. Students will then place the washers on top of the plastic directly above the cup.
7. Have students place the tray under the heat lamp and leave it there for at least 40 minutes. Make sure that they note the time they placed the tray under the lamp and record it on a separate sheet of paper. This will be their data sheet.
8. Have students go back after 40 minutes and dismantle their apparatus. Record how long the tray was under the lamp and measure the amount of water collected using the graduated cylinder.
9. Using the student worksheet, have students evaluate the pros and cons of using this type of solar water collector on the Moon.

Management

- Divide students into cooperative groups (small teams are preferred, but larger ones can be used if there are not enough materials to go around).
- One 50-minute class period

Reflection & Discussion

1. Building upon the questions they answered on their worksheets, discuss with students the pros and cons of a similar sun-powered device to retrieve lunar water. Some of them may include:

Pros:

- The simple design reduces the amount of materials that would need to be transported to the Moon.
- Solar energy is a resource that is readily available.
- A solar water collecting system would do little to no damage to the lunar surface.

Cons:

- While all latitudes and longitudes of the Moon receive sunlight, only half of the Moon receives sunlight at any given time.
- In the shadows of craters, where water is believed to exist, sunlight never touches the surface.
- The equatorial region of the Moon is a more convenient place to build a human habitat because it is more accessible.

Transfer/Extensions

1. Design and test another method of extracting water from the simulated soil.
2. Research the methods NASA is considering for extracting water from the lunar surface.

Water on the Moon

Student Procedures

1. Take a pan of simulated frozen lunar regolith and place the paper cup in the center of the tray. If the cup is taller than the side of the tray, trim the cup so that it sits about 2 cm lower than the side of the tray.
2. Seal the top of the tray with plastic wrap. Secure the plastic wrap over the tray with tape so that, when weighted with the washers, it droops slightly. However, the plastic should not be so loose that it touches the rim of the cup.
3. Place the washers on top of the plastic directly above the cup.
4. Place the tray under the heat lamp and leave it there for at least 40 minutes. Make sure that you note the time that you placed the tray under the lamp and record it on a separate sheet of paper. This will be your data sheet.
5. Go back after 40 minutes and dismantle your filter. Record how long the tray was under the lamp and measure the amount of water collected using the graduated cylinder.
6. Using the table below, evaluate the pros and cons of using this type of solar water collector on the Moon. You might consider such things as: the location of the unmined water; the topography of the Moon; ease of transportation; and environmental preservation. When you're finished, answer the Questions & Conclusions questions on a separate sheet of paper.

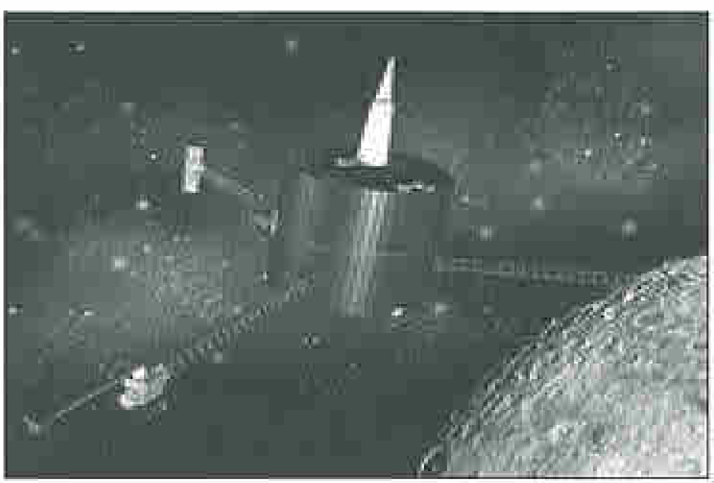


Image courtesy of NASA

Lunar Prospector

Pros of the solar collector

Cons of the solar collector

Questions & Conclusions:

1. How much water were you able to extract?
2. Consider how much water was collected and how long it took. Do you think this is an efficient method for collecting water? Explain.
3. Would you recommend this method to NASA? Why or why not?

Distance to the Moon

Background

In astronomy, distances and sizes are...astronomical. One must travel hundreds of thousands of miles to visit even the closest planetary neighbor in the Solar System, our Moon. However, this is a small leap relative to the millions of miles between the Earth and other planets.

Because of its proximity, the Moon has been visited frequently by spacecraft. It takes only a few days to reach the cratered satellite from Earth. Unmanned spacecraft in the forms of orbiters, lunar landers, and rovers have been visiting the Moon since the late 1950's, and continue to make unexpected discoveries. The Moon has even hosted human astronauts for brief stays of a few days during the late 1960's and early 1970's—so far the only object close enough to the Earth to make such an exploration possible.

While the manned Apollo missions required a supporting cast of thousands back at Earth, it doesn't take a rocket scientist to calculate the distance to the Moon. All one needs is a basic understanding of geometry and knowledge of the diameter of the Moon. In this activity, students will use a simple observation of the Moon and a few calculations to determine for themselves the lunar distance.

Topic

Lunar Distance

Objectives

Students will:

- Predict the distance between the Earth and Moon using a globe and a softball.
- Determine the actual distance to the Moon.

Overview

In this activity students will first try to determine the location of the Moon using a globe and softball for their scale model. In the second part of this activity students will construct a Moon viewer and they will calculate the distance to the moon.

Key Question

How far away is the Moon?

Key Concept

- The distance to the Moon can be determined without ever leaving the Earth.

Materials & Preparation

Part 1
- Index card
- Transparent tape
- 2 meters of string
- Metric ruler

Part 2
- 15 meters of string
- Softball
- 16" diameter globe or Earth ball
- Scissors

Part 1 Demonstration

1. Review how to solve for a variable in an equation.
2. Students will create a Moon viewer by cutting a 1cm diameter half-circle in the edge of an index card. Be careful in measuring and cutting the shape to ensure a more accurate Moon distance measurement.
3. Have students tape the end of a 2 meter long string to the bottom center of the semi-circular cutout.
4. Students will then tape the card to a window through which they can view the Moon. This can be done during the daytime or at night, as long as the Moon is visible through the window. The activity is easier when the phase is near full, although keep in mind that the full Moon does not rise until about 6:00 in the evening.
5. Have students sight the Moon through the semi-circular cutout of their Moon viewer while holding the string next to their eyes.
6. They will have to adjust their distance from the Moon viewer and let the string slide through their fingers to keep it taut. They have reached the correct distance when the Moon appears to just fill the cutout.
7. On the string, have the students mark the location of their eye with an ink pen. Students will measure the distance, in centimeters, from the Moon viewer to their eye and record this measurement.

8. Discuss with students how the triangles with the Moon and the Moon viewer are similar, and what this means about their bases and heights.
9. Students will then perform the calculations to find the distance from the Earth to the Moon:

$$\frac{\text{The distance to the Moon}}{\text{Diameter of the Moon}} = \frac{\text{The distance to your eye from the viewer (in centimeters)}}{\text{Diameter of the Moon viewer (1 cm)}}$$

10. The light from each side of the Moon forms a triangle with the location of the eye. The Moon viewer creates a scaled version of that triangle. Since both of these triangles are similar triangles, their bases and heights are proportional.
11. To solve for the unknown of the Moon distance multiply both sides of the equation by the diameter of the Moon. This leaves the final equation the students need:

$$\text{The distance to the Moon} = \frac{\text{The distance to your eye from the viewer (in cm's)} \times \text{Diameter of the Moon}}{\text{Diameter of the Moon viewer (1 cm)}}$$

The diameter of the Moon is 3476 kilometers. Calculate the distance to the Moon using this equation.

12. When completed, the students should get answers close to 384,000 kilometers. DO NOT GIVE THIS ANSWER AWAY. Use it only as a method to gauge the students' understanding of the material.

Part 2 Demonstration

1. Assign students to groups of four.
2. Discuss the distances between the Earth and other celestial bodies such as the Moon, Sun and planets.
3. Place a globe or ball representing the Earth near one corner of the room. Ask each group to come to a consensus as to where to place the Moon (softball) so that it is at the correct scaled distance.
4. Send one member of each group to stand at the location decided on by the group, placing the Earth and the Moon in a position relative to their size and distance from each other.
5. After each group has decided where to place the Moon, take the 15 meter-long string and wrap it around the globe nine and a half times. Cut off any excess string. The resulting length of the string will approximately equal the distance to the Moon (384,000 km).
6. Stretch out the string so one end of the string lies at the center of the Earth and the other end lies at the center of the Moon. Have the groups check their original prediction of the location of the Moon.
7. Now to give students some pespective, fold the string in half and cut it. Repeat nine times until the string is about a half-inch long. This is the distance to the Hubble Space Telescope (400 miles) from the surface of the earth. It is also the distance to where the Space Shuttle orbits.
8. To give students perspective of this distance, place the piece of string on a map so they can see the distance relative to home. For example if you were in Washington DC the distance to the Shuttle would be closer than the distance to Florida.

Management

- Divide students into cooperative groups.
- One 50-minute class period.

The Full Moon does not rise until 6:00 at night. You may choose to do this activity around the First Quarter Moon, which is clearly visible under clear skies during the afternoon hours, although the results may not be as accurate. Alternatively, you may simply send the activity home with students as a take-home project. If the students do not have a Moon-facing window, they may choose to mount the index card on a stick or other temporary device and perform the activity outdoors.

Transfer/Extension

1. The Sun appears to be the same size as the Moon in the sky. However, the Sun is actually about 400 times as wide as the Moon. What is the distance to the Sun?

Distance to the Moon

Student Procedures

1. Create a Moon viewer by cutting a 1 cm diameter half-circle in the edge of an index card. Be careful in measuring and cutting the shape to ensure a more accurate Moon distance measurement.
2. In your data table record the diameter of your half-circle.
3. Use tape to attach the end of a 2 meter long string to the bottom center of the semi-circular cutout.
4. Tape the card to a window through which you can view the Moon. This can be done during the daytime or at night, as long as the Moon is visible through the window. (See your teacher for alternatives if you cannot view the Moon this way.)
5. Sight the Moon through the semi-circular cutout of your Moon viewer while holding the string up to your eye level.
6. Slowly adjust your distance from the Moon viewer and let the string slide through your fingers to keep it taut. You have reached the correct distance when the Moon appears to just fill the cutout.
7. Mark the location of your eye on the string with an ink pen. Then, measure the distance, in centimeters, from the Moon viewer to your eye.

$$\text{The distance to the Moon} = \frac{\text{The distance to your eye from the viewer (in centimeters)}}{\text{Diameter of the Moon viewer (1cm)}} \times \text{Diameter of the Moon}$$

Data Table	
Diameter of half circle of the Moon viewer	______
Distance from your eye to Moon viewer	______
Diameter of the Moon	3476 km
Distance to the Moon	______

8. To solve for the unknown of the Moon distance use the equation. (Be sure to show your work.)

Questions and Conclusions

1. How did the prediction you made for the lunar distance match up to the actual distance?
2. Compare the orbit of the Space Shuttle with that of the Moon. Why do you think we have returned humans to Earth orbit many more times than the Moon? Do you think we will ever send humans to the Moon again? Why or why not?
3. Can you think of any other situations where knowing how to calculate distances (using this method) might be helpful?
4. Research the actual distance from the Earth to the Moon and check your results.

Extending The Mission

Suggested Extensions

After completing the activities in this book there are many directions in which to lead your students to learn more about the Moon. Below are guidelines for two extension activities. The first is a discussion which can potentially lead to a debate. The second is a hands-on activity for individuals or small groups.

Suggestion #1: Debate

The Moon does not belong to any one country. However there are indications that the Moon may have valuable resources. Should governments or private industries be allowed to mine Moon resources for profit?

- How do you decide which countries have the right to lunar resources?
- Should the Moon's resources be preserved so as not to contaminate scientific studies?
- Should private industries be allowed to make a profit from lunar resources?

Suggestion #2: Press Kit

Have each student imagine that he or she is a team member of a mission to return to the Moon. This press kit will represent every aspect of the fictional mission from beginning to end. The way it is presented should be up to the student, but below are some guidelines to get started:

- A press release announcing the mission and its team members.
- A biography sheet of the student with the title of his/her job and how the job relates to the mission.
- A mission statement including a timeline, plan for research and goals.
- Pictures of the spacecraft both inside and out.

Glossary

Anorthosite–The predominant rock of the lunar highlands.

Breccia–A rock made from angular fragments cemented together.

Celestial–Of or having to do with the skies or visible heavens (the Sun, Moon, stars, and planetary bodies).

Composition–The chemical makeup of an object.

Crescent Moon–Moon phase with less than one-half of the side facing Earth illuminated.

Diameter–The distance across a circle through its center. Also, distance through a sphere measured through the center of the sphere.

Ejecta–Material blown out of a crater during an impact on the surface.

Erosion–The wearing away of a planetary surface by some natural process such as lava flow, bombardment, wind, water, or another mechanism.

First Quarter Moon–Moon phase between the New and Full Moon where exactly half of the side facing Earth is illuminated. This phase occurs approximately one week after a New Moon.

Full Moon–A phase of the Moon in which the entire side facing Earth is illuminated by sunlight.

Geologist–A scientist who studies the formation, structure, history, and processes (internal and on the surface) that change Earth and other planetary bodies.

Gibbous Moon–Moon phase occurring when more than half (but not all) of the side facing Earth is illuminated.

Igneous Rock–Rock formed from cooled and hardened magma.

Impact Crater–A circular depression in the ground caused by meteoroids or asteroids hitting the surface of a planet.

Lunar–Relating to the Moon.

Magma–Melted rock located deep below the surface of a planet, such as Earth, or a moon.

Maria–Low areas on the Moon that appear dark and smooth. Maria are formed by ancient lava flows.

Metamorphic Rock–Rock formed from pre-existing rocks as a result of intense heat, pressure, or chemical processes.

Meteoroid–A small solid body moving through space in orbit around the Sun.

Moon–The name of the Earth's only natural satellite.

Moon Phases–The monthly changes in the appearance of the Moon as seen from Earth. Phases are caused by the Moon's revolution around Earth.

New Moon–A phase of the Moon in which none of the side facing Earth is illuminated by the Sun.

Regolith–A powdery soil layer on the Moon's surface caused by bombardment by meteoroids.

Sedimentary Rocks–A type of rock formed from hardened deposits of sediments.

Sublimation–The process of a solid returning directly to a gas, without changing to a liquid first.

Terrestrial–Relating to the Earth and its inhabitants. Belonging to a class of planets that are like the Earth.

Third Quarter Moon–Moon phase between the Full and New Moon where exactly half of the side facing Earth is illuminated. This phase occurs approximately one week after a Full Moon.

Waning–The Moon is said to be waning in its phase cycle as the amount of light reflected off of the lunar surface towards the Earth decreases. This occurs as the cycle progresses from Full Moon to New Moon.

Waxing–The Moon is said to be waxing in its phase cycle as the amount of light reflected off of the lunar surface towards the Earth increases. This occurs as the cycle progresses from New Moon to Full Moon.

Weathering–The action of elements in altering the color, texture, composition, or form of exposed objects on the surface of a planet or Moon.

Resources

The following is a list of websites, organizations, and magazines teachers can consult for more information about the Moon.

Web Resources

Challenger Center OnLine http://www.challenger.org
In addition to links to the sites below, this web site has downloadable worksheet-quality classroom activities, called Lessons Launchers, as well as great links, space clipart, news, and information about our education simulation programs.

The Moon http://www.seds.org/billa/tnp/luna.html
This site is great for lunar researchers. It provides loads of information about lunar missions past, present, and future. Included you will discover amazing photographs and statistics of the Moon, Earth, and Mars, as well as links to more websites.

Project Apollo http://www.ksc.nasa.gov/history/apollo/apollo.html
Very straightforward, this site provides concise information about all the Apollo Missions, along with pictures of each spacecraft mission, and mission patches.

Future Lunar Missions http://cass.jsc.nasa.gov:80/expmoon/future/future.html
Exploration of the Moon is by no means complete. This page provides some information on plans for future missions to the Moon. It also answers questions that are posed about past and recent missions.

Earth and Moon Viewer http://www.fourmilab.ch/earthview/vplanet.html
This site allows you to view a map of the Earth showing the day and night regions at this moment. You can also view the Earth from the Sun, the Moon, the night side of the Earth, above any location on the planet specified by latitude, longitude and altitude, from a satellite in Earth orbit, or above various cities around the globe.

Everything You Ever Wanted to Know About the Moon
http://www.tsgc.utexas.edu/everything/moon/
Very student friendly, this site answers questions like, "How much would you weigh on the Moon?" or "How many people have actually set foot on the Moon?". You can also take the Moon quiz to see how much you already know about the Moon.

Clementine http://www.nrl.navy.mil/clementine/clementine.html
This site provides the viewer with specific information about the Clementine mission and spacecraft, along with a variety of photos taken from Clementine while in space.

Non-Web Resources

Challenger Center for Space Science Education: Mixing a little adventure with education has proven to be a recipe for success, resulting in a vibrant, growing portfolio of Learning EdVentures programs. Classroom programs include:

Cosmic EdVentures: Exploring Earth's Neighborhood (grades 3-6): Cosmic EdVentures creates a simulation for upper elementary and middle school students in which they apply for and are accepted to work for Cosmic EdVentures, Challenger Center's travel agency on board the futuristic Millennium Station.

When students are accepted to Cosmic EdVentures Academy, they become Planetary Excursion Planners, or PEPs for short. PEPs become space savvy as they complete three levels of coursework: Solar System Basics, Planetary Features, and Planetary Excursions. These courses contain hands-on activities about the Solar System, the features of planets and moons, and Solar System travel. PEPs are tested on content, build portfolios, and make team presentations.

Mars City Alpha (grades 5-8): This exciting classroom simulation transforms students into scientists and engineers launching an international effort to design a settlement on Mars. Students work in teams to prepare for the culminating event, the building of a tabletop model of a futuristic human settlement on Mars. Mars City Alpha meets science education standards and benchmarks while providing many memorable crosscurricular learning opportunities. Mars City Alpha™ received Learning Magazine's coveted Teacher's Choice Award in 1994.

Marsville: A Cosmic Village (grades 5-8): Marsville is a classroom-based project that allows students to create a prototype habitat for Mars. Students create their own living environment using a multitude of interdisciplinary skills. The program culminates with a link-up day when all the classes rendezvous at one site to construct their cosmic village and share the experience of creating a settlement on Mars.

Vista Station (grades 3-4): Vista Station is an innovative mix of the arts and sciences that creates a dynamic setting from which students launch a series of seven themed educational adventures called "Mini-EdVentures." Self-contained and ready to use, each of the seven Mini-EdVentures provide both the tools for transformation and some of the biggest WOW's of space learning. Vista Station will engage your learners in learning about living and working in space. All seven modules function independently of one another and are designed for maximum ease of use as well as grade-level flexibility.

EdVenutures in Simulation: A Great START to the 21st Century: EdVentures in Simulation is a professional development workshop sharing the secrets behind Challenger Center's simulations based on more than 10 years of experience conducting successful simulation programs. The Challenger Learning Center network reaches more than a quarter of a million students and teachers each year with full immersion simulations at sites across North America, Canada, and the United Kingdom.
For more information, please visit www.challenger.org or call 888-683-9740.

Astronomical Society of the Pacific: ASP has a free quarterly educational newsletter, a catalog full of great educational items, and Project ASTRO's Universe at Your Fingertips (see below). For more information, contact ASP, 390 Ashton Ave., San Francisco, CA 94112. Call (415) 337-1100.

Harvard-Smithsonian Center for Astrophysics: CFA offers broadcast and instructional television programs, in-service and preservice workshops, and a physical science curriculum for elementary students called Project ARIES, among other programs. CFA can be contacted at 60 Garden Street, Cambridge, MA 02138.

Lawrence Hall of Science GEMS: Great Explorations in Math and Science (GEMS) is a growing resource for activity-based science and mathematics developed by the University of California at Berkeley's Lawrence Hall of Science. For a free GEMS catalog (another must), write LHS GEMS, University of California, Berkeley, CA 94720. Call (510) 642-7771.

Lunar & Planetary Institute: This branch of the Center for Advanced Space Studies is part of the Universities Space Research Association (USRA) that offers specialized slide sets for educators on a variety of Solar System topics. Contact LPI, Order Dept., 3600 Bay Area Blvd., Houston, TX 77058. Call (281) 486-2172.

NASA CORE: The Central Operation of Resources for Educators for NASA generated materials. CORE, Lorain County JVS, 15181 Rt. 58 South, Oberlin, OH 44074. Call (216) 774-1051, ext. 293 or 294.

National Space Society: With membership comes a subscription to NSS' *Ad Astra* magazine, a great way to stay in touch with the current events and issues surrounding space exploration. NSS, 600 Pennsylvania Avenue, SE, Suite 201, Washington, DC 20003. Call (202) 543-1900.

The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook: Published by the Astronomical Society of the Pacific and its Project ASTRO, this comprehensive and ready-to-use collection of classroom activities, teaching ideas, and annotated resource lists is a must-have resource for every school in the country! For around $30, it is a bargain that cannot be passed up. Call (800) 335-2624, or write to the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

Challenger Center For Space Science Education

Challenger Center for Space Science Education is a global not-for-profit education organization created in 1986 by the families of the astronauts tragically lost during the last flight of the Challenger Space Shuttle. Dedicated to the educational spirit of that mission, Challenger Center develops Learning Centers and other educational programs worldwide to continue the mission to engage students in science and math education. Challenger Center's network of Learning Centers throughout the Unites States, Canada, and the United Kingdom have been recognized leaders in educational simulation, with a strong standards-based emphasis. Challenger Learning Centers and Challenger Center's award-winning classroom and teacher training programs all use the excitement of space exploration to create positive learning experiences that:

- Raise students' expectations of success;
- Foster in them a long-term interest in math, science, and technology; and
- Helps them develop critical communication, decision-making, team-building, and collaborative skills.

For a Challenger Learning Center in your area, please visit us at www.challenger.org.

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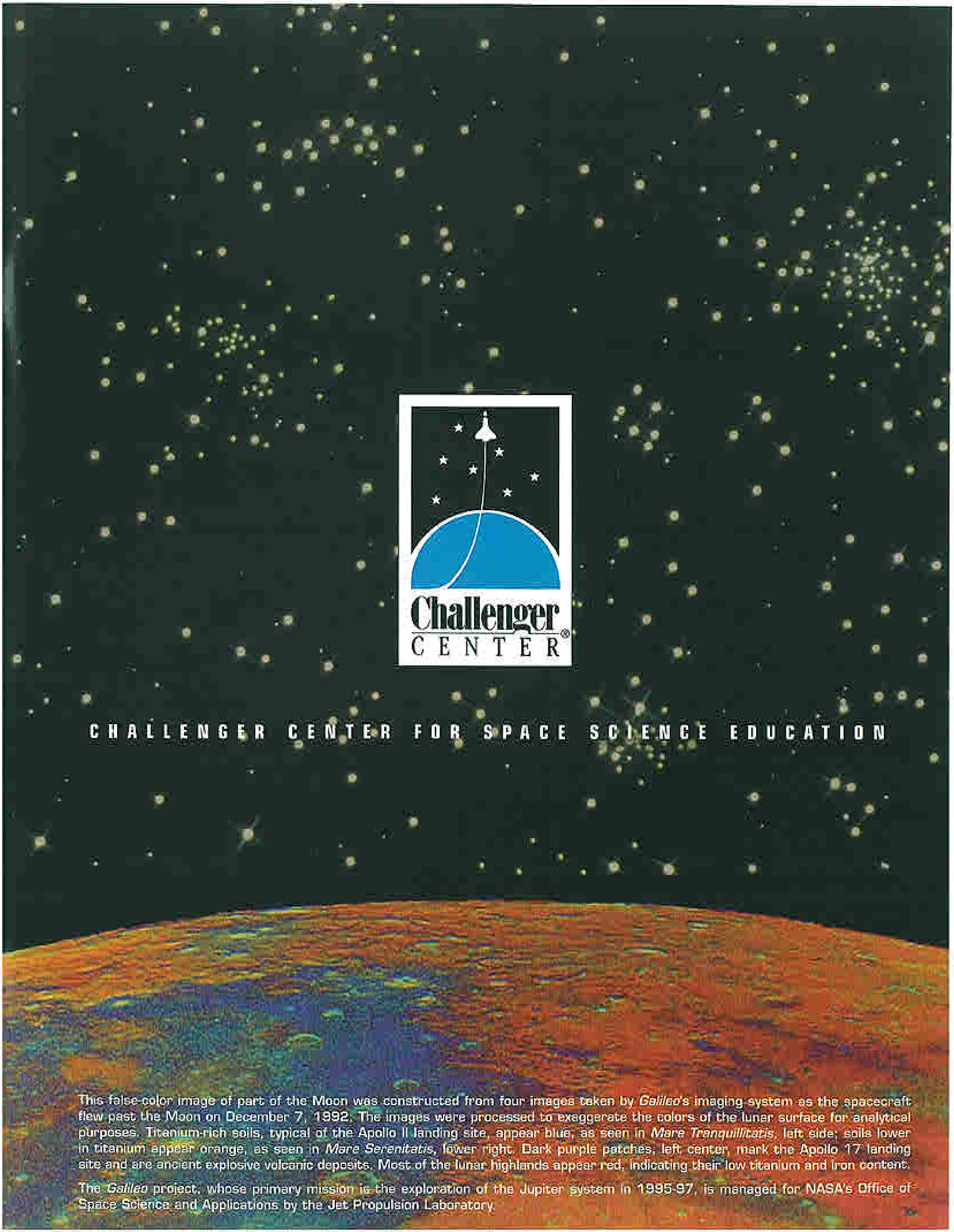
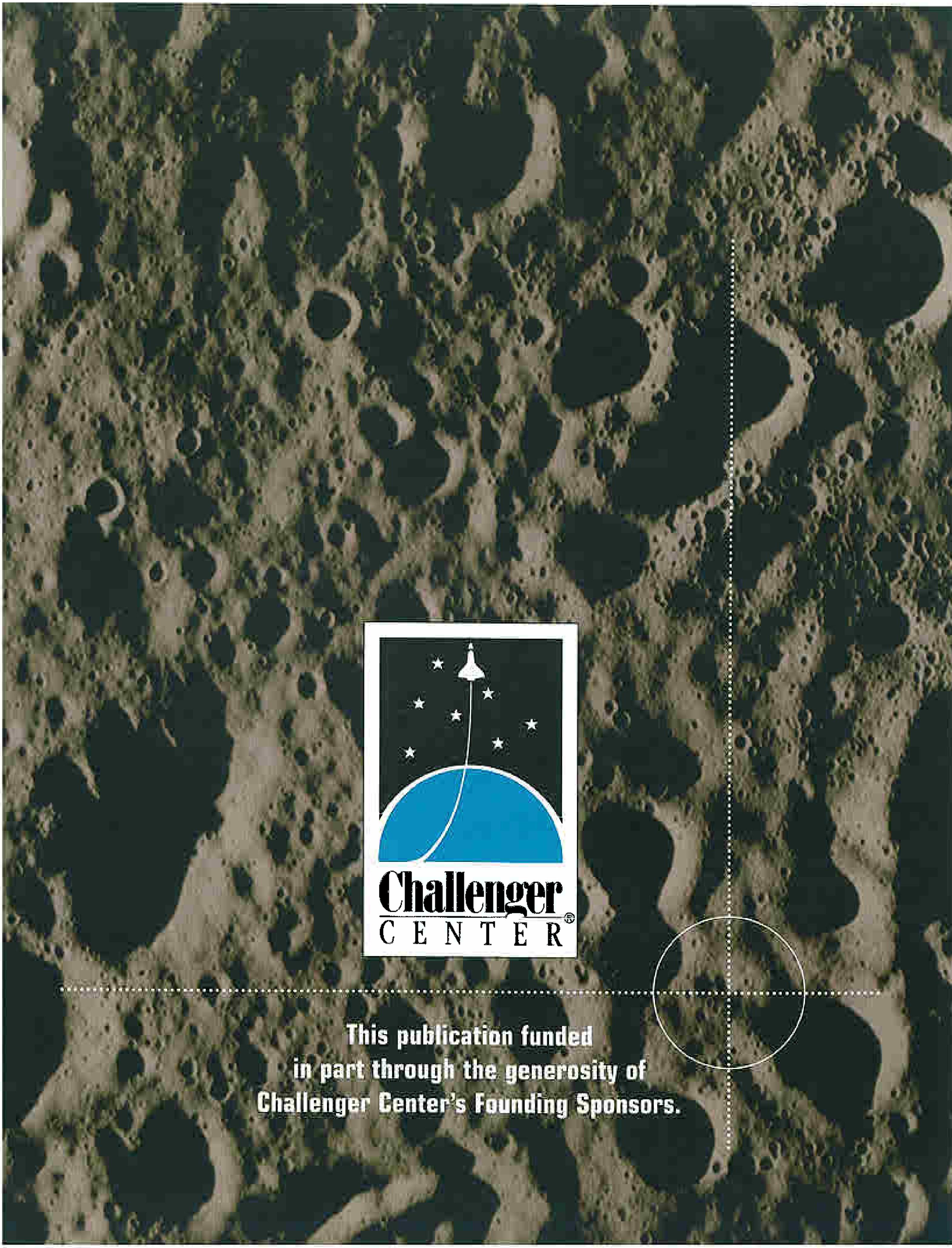


This false-color image of part of the Moon was constructed from four images taken by *Galileo*'s imaging system as the spacecraft flew past the Moon on December 7, 1992. The images were processed to exaggerate the colors of the lunar surface for analytical purposes. Titanium-rich soils, typical of the Apollo II landing site, appear blue, as seen in *Mare Tranquillitatis*, left side; soils lower in titanium appear orange, as seen in *Mare Serenitatis*, lower right. Dark purple patches, left center, mark the Apollo 17 landing site and are ancient explosive volcanic deposits. Most of the lunar highlands appear red, indicating their low titanium and iron content.

The *Galileo* project, whose primary mission is the exploration of the Jupiter system in 1995-97, is managed for NASA's Office of Space Science and Applications by the Jet Propulsion Laboratory.



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